THE NEARSHORE WATER QUALITY OF NOTTAWASAGA BAY

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THE NEARSHORE WATER QUALITY OF

NOTTAWASAGA BAY

1980

by
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I SUMMARY

During the 1980 ice-free period, nearshore water quality between Cape Rich and Cedar Point in Nottawasaga Bay was surveyed. Only two localized areas showed clear signs of eutrophication, one at the mouth of the Nottawasaga River and the other at the mouth of Collingwood harbour; these affected areas did not extend to the Mary Ward Shoals, a major fish spawning ground susceptible to growth of the attached alga Cladophora. Oligotrophy characterized the open bay and the remainder of the nearshore, although differences between these two zones were apparent. Slightly elevated nutrient levels and the presence of bloom-forming algae in the remote nearshore may represent initial signs of eutrophication.

II FUTURE CONCERNS

A new municipal sewage treatment plant servicing the area between Collingwood and Thornbury is currently under construction at Long Point. Total phosphorus concentration in the effluent will be limited to 0.3 mg/L and discharge will occur off the lakeward edge of the sensitive Mary Ward Shoals. These design criteria should minimize any "immediate" deterioration in nearshore water quality from the growth of Cladophora; however, an increase in phosphorus loadings to the offshore waters of Nottawasaga Bay will still result (albeit to a lesser extent than without strict controls). It is likely that phosphorus loadings to Nottawasaga Bay will continue to increase in the future as existing sewage treatment facilities are expanded and new ones constructed to cope with an increasing population. The concern for the future is that unless sewage disposal methods other than direct discharge to Nottawasaga Bay are eventually employed, water quality may deteriorate over the "long term" because of the effects of basin wide nutrient enrichment.

III RECOMMENDATIONS

To protect Lake Huron from environmental degradation due to the growth of nuisance algae, especially Cladophora, every effort should be expended to:

i. Maintain background total phosphorus concentrations below 0.005 mg/L which Jackson and Hamdy (1982) believe approximates the lower nutritional limit for Cladophora growth.

ii. Improve agricultural methods to reduce nutrient (especially phosphorus) inputs associated with agricultural runoff from the Lake Huron watershed.

iii. Control nutrient (especially phosphorus) inputs from municipal and industrial sources by strictly limiting effluent nutrient concentrations and by opting for methods of effluent disposal other than direct discharge to the Lake.

iv. Implement an annual water quality surveillance plan for Lake Huron to measure the effectiveness of abatement activities and to identify emerging problems.

IV INTRODUCTION

In 1974, at the request of the International Joint Commission and under the direction of the Upper Lakes Reference Group, the Ontario Ministry of the Environment and Environment Canada surveyed the water quality of Georgian Bay (ULRG 1977). No evidence of significant pollution in the open waters of Georgian Bay was found. Nevertheless, certain localized nearshore areas, primarily embayments, river mouths and harbours, showed signs of eutrophication (an enrichment process leading ultimately to fish kills, aquatic habitat degradation and fouling of water supplies). In order to determine the extent of eutrophication and ensure the protection of open bay waters, further surveillance of affected nearshore areas was recommended. This investigation, as part of the Great Lakes International Surveillance Plan for Lake Huron, Georgian Bay and the North Channel, addresses the extent of eutrophication in nearshore Nottawasaga Bay during the ice-free period of 1980.

V STUDY AREA AND WATER USES

The Nottawasaga Bay drainage basin, at the extreme southern end of Georgian Bay, is composed primarily of limestone bedrock overlain by clay-sand soil (Fig. 1). A large portion of the basin (63%) is forest; 23% is pasture and 7% cropland. Only about 2% of the basin is affected by urban development, although considerable future development is planned. Between Cape Rich and Cedar Point, four river systems drain the watershed: the Nottawasaga, Pretty, Beaver and Bighead Rivers. Each of these rivers supports a town of moderate size and each town relies on the Bay for its water supply and/or as a receiving body for waste water discharge (treated municipal sewage, storm sewer runoff); only Collingwood currently removes phosphorus from its treated municipal sewage (Table 1).

Nottawasaga Bay is popular cottage country. Local populations often triple over summer months and beach areas are extensively used for recreation. The area also supports a number of important fisheries. Sport fish include rainbow trout and splake, while the commercial fishery (primarily whitefish, splake, chub, yellow perch and yellow pickerel) accounts for a catch of 100,000 pounds of fish

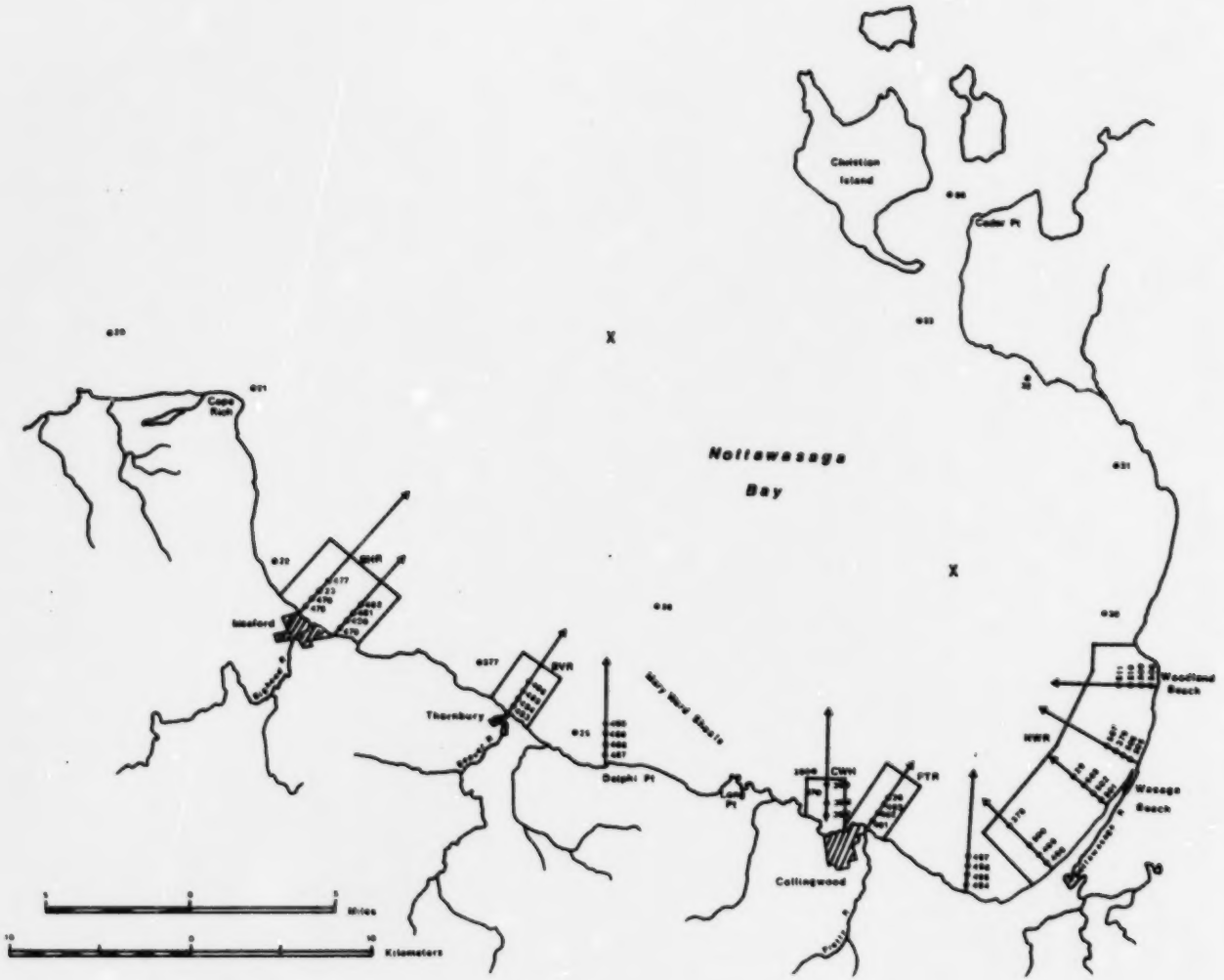

Fig. 1 Nearshore Nottawasaga Bay sample sites and site groups, 1980.

Data at open bay sites (x) were provided courtesy of Environment Canada.

Table 1. Population, municipal works and hydrological details of the Nottawasaga Bay drainage basin (Anon 1969, Anon 1981, MOE 1973-79, MOE 1977, MOE unpublished).

BIGHEAD RIVER	Drainage Area	293 km^2
	Annual Mean Discharge Rate	5.93 m^3/sec
MEAFORD	Population	4,277 (1980)
	Water Supply	Nottawasaga Bay offshore (chlorinated)
	Drawing Rate	1.4 x 10^3 m^3/day
	Sewage Treatment	High rate extended aeration
	Effluent Discharge Rate	2.7 x 10^3 m^3/day to Nottawasaga Bay offshore
BEAVER RIVER	Drainage Area	572 km^2
	Annual Mean Discharge Rate	8.8 m^3/sec
THORNBURY	Population	1,427 (1980)
	Water Supply	Beaver R. (chlorinated)
	Drawing Rate	ND
	Sewage Treatment	Aerated cell and lagoon
	Effluent Discharge Rate	0.88 x 10^3 m^3/day to Beaver R.
PRETTY RIVER	Drainage Area	185 km^2 (includes Batteaux R. and Silver Cr.)
	Annual Mean Discharge Rate	1.2 m^3/sec
COLLINGWOOD	Population	11,730 (1980) 35,000 (2011 Target)
	Water Supply	Nottawasaga Bay offshore (chlorinated)
	Drawing Rate	10.5 x 10^3 m^3/day
	Sewage Treatment	Primary with phosphorus removal
	Effluent Discharge Rate	15.9 x 10^3 m^3/day to Collingwood harbour
NOTTAWASAGA RIVER	Drainage Area	1,181 km^2
	Annual Mean Discharge Rate	9.2 m^3/sec
WASAGA BEACH	Population	4,600 (11,000 in summer) (1979) 15,000 (2011 Target)
	Water Supply	Deep wells
	Drawing Rate	ND
	Sewage Treatment	Lagoon
	Effluent Discharge Rate	Overflow to Nottawasaga R.

Note: Each town has one or more storm sewers that empty directly into Nottawasaga Bay.
ND No data.

annually and employs thirteen professional fishermen (Ontario Ministry of Natural Resources unpublished data).

VI METHODS

In 1980, fifty-six sample sites were allocated to the nearshore zone of Nottawasaga Bay. Transects comprised of three or four sample sites were located off rivers (Nottawasaga, Pretty, Beaver; Bighead) and harbours (Collingwood) and areas of special concern (Mary Ward Shoals), while individual sites were located throughout the remainder of the nearshore. Four synoptic cruises were carried out during the ice-free period: spring (early June), summer (July-August), fall (September) and late fall (November). Each sample site was usually visited on three consecutive days on each cruise. At each site, Secchi depth was recorded (in duplicate) and samples for water chemistry (including chlorophyll a) were collected at 1.5m depth (phytoplankton taxonomy and biomass samples were collected as composites through 2X the Secchi depth). Analyses included: total and soluble reactive phosphorus; ammonia, nitrate-nitrite and total Kjeldahl nitrogen, reactive silicate, chloride, conductivity and chlorophyll a. Bacterial counts (total coliform, fecal coliform, fecal streptococci and Pseudomonas aeruginosa) were determined in triplicate at each site for the summer cruise only, while estimates of phytoplankton biomass and taxonomic composition where recorded at a reduced number of sites (nine) once during spring, summer and fall. All chemical and biological analyses were performed at the Ministry of the Environment Laboratory in Rexdale, Ontario according to standard analytical methods (MOE 1981; Nicholls et al. 1977).

VII RESULTS AND DISCUSSION

To assess localized enrichment effects sample sites in Nottawasaga Bay were divided into seven groups (Fig. 1). The first five groups, each encompassing one to four transects, were located off river and harbour mouths. The sixth group included the remaining nearshore sites remote from the potentially affected locations. Two open bay sites, which formed the seventh and final site group, were included for nearshore/offshore comparison.

7.1 NUTRIENTS

Phosphorus

The Mary Ward Shoals of Nottawasaga Bay, a major fish spawning ground located west of Collingwood, are susceptible to environmental degradation from the effects of anthropogenic phosphorus (P) enrichment. These extensive and exposed rocky shallows provide a highly favourable physical habitat for the attached alga Cladophora; however, background phosphorus concentrations are apparently too low to support widespread growth (Neil and Owen 1964, Auer and Canale 1980, Jackson and Hamdy 1982; Jackson 1985).

Yearly (ice-free) mean concentrations of total P for the nearshore site groups in Nottawasaga Bay ranged from 0.004 to 0.006 mg/L, while mean levels of soluble reactive phosphorus (SRP), a bioavailable measure of the nutrient, varied from 0.002 to 0.003 mg/L. In the open bay, yearly mean concentrations of total P and SRP were 0.004 and less than 0.001 mg/L, respectively (Table 2).

Early spring runoff from the Nottawasaga River resulted in considerable nutrient loading to the Wasaga Beach area (Fig. 2). The mean total P concentration at this time was 0.008 mg/L: in summer, levels were similar at 0.009 mg/L. The Collingwood harbour area had relatively low spring total P values, but increased discharge from the harbour in summer boosted mean levels to a yearly high of 0.011 mg/L; both of these areas had reduced mean total P concentrations in the fall and late fall.

Elevated total P concentrations were evident to about 1.5 km off the Nottawasaga River and Collingwood harbour, while the Pretty River, Beaver River and Bighead River showed only minimal or no apparent lakeward effects (Fig. 3). The restricted distribution of phosphorus enrichment in Nottawasaga Bay is apparent in Fig. 4 which depicts the "maximum" mean total P concentration at each site over the four sampling cruises. It is also apparent that the remote nearshore had elevated total P slightly above open bay levels. This may reflect natural littoral zone processes (i.e., wave induced sediment resuspension) and/or initial signs of artificial enrichment.

Table 2. Summary of water quality indicators in Nottawasaga Bay for the ice-free period (spring, summer, fall, late fall), 1980. Yearly mean precedes minimum-maximum values.

	Nottawasaga R. (Wasaga Beach)	Pretty R. (Collingwood)	Collingwood Harbour	Beaver R. (Thornbury)	Bighead R. (Meaford)	Remote Nearshore	Open Bay
Total P (mg/L)	0.006 (0.001-0.028)	0.004 (0.001-0.013)	0.006 (0.001-0.029)	0.004 (0.001-0.009)	0.004 (0.001-0.009)	0.005 (0.001-0.026)	L0.004 (L0.003-0.005)
SRP (mg/L)	0.002 (0.001-0.007)	0.002 (0.001-0.005)	0.003 (0.001-0.088)	ND	ND	0.002 (0.001-0.007)	0.001 (0.001-0.001)
$NO_3 + NO_2$ (mg/L)	0.260 (0.180-0.595)	0.249 (0.195-0.300)	0.248 (0.192-0.300)	0.252 (0.220-0.280)	0.251 (0.195-0.290)	0.246 (0.105-0.320)	0.252 (0.232-0.284)
NH_3 (mg/L)	0.010 (0.002-0.074)	0.012 (0.002-0.024)	0.018 (0.006-0.080)	0.010 (0.004-0.030)	0.012 (0.002-0.062)	0.011 (0.002-0.044)	0.002 (0.001-0.003)
TKN (mg/L)	0.184 (0.100-0.420)	0.170 (0.120-0.320)	0.194 (0.110-0.400)	0.148 (0.110-0.240)	0.151 (0.110-0.370)	0.166 (0.100-0.410)	0.163 (0.114-0.268)
R. Silicate (mg/L)	0.66 (0.25-2.45)	0.51 (0.40-0.60)	0.51 (0.20-0.60)	0.50 (0.40-0.65)	0.51 (0.44-0.70)	0.96 (0.34-1.80)	(0.82-1.19)
Cond (uS/cm)	207 (190-390)	195 (190-205)	198 (190-232)	194 (185-215)	194 (186-205)	188 (180-213)	(180-197)
Cl (mg/L)	5.3 (4.8-10.0)	5.0 (4.9-5.5)	5.1 (4.9-6.8)	5.0 (4.8-5.4)	5.0 (4.8-5.4)	4.9 (4.8-6.2)	(4.1-5.2)
Secchi Depth (m)	3.8 (0.5-8.0)	5.3 (1.3-10.0)	3.5 (1.0-6.0)	5.5 (2.3-10.0)	6.3 (1.8-10.5)	ND (2.0-15.5)	
Chl *a* (ug/L)	0.87 (0.10-8.80)	0.65 (0.10-2.50)	0.69 (0.10-1.90)	0.54 (0.10-1.00)	0.56 (0.10-1.20)	ND (0.10-1.30)	

ND No data.
L Less than.

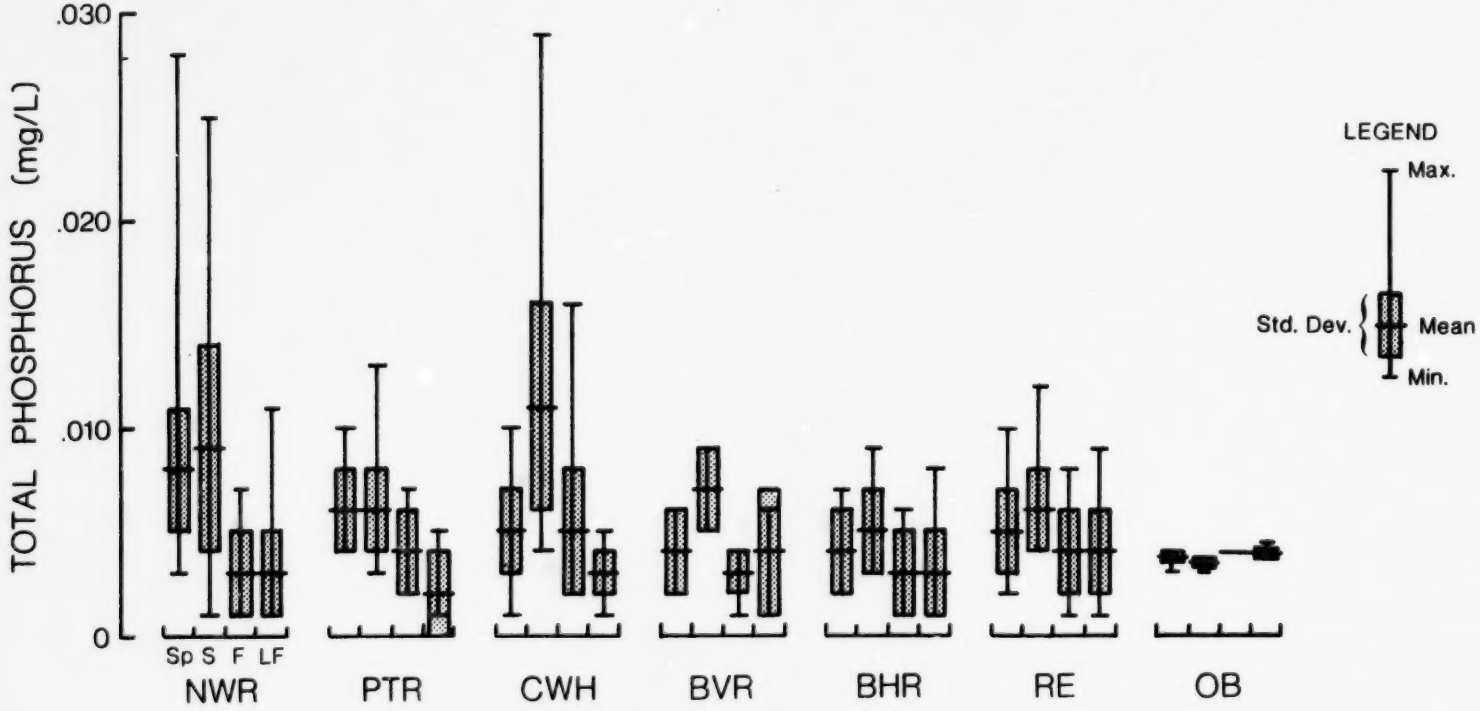

Fig. 2 Total phosphorus summary statistics for site groups in Nottawasaga Bay during spring (SP), summer (S), fall (F) and late fall (LF), 1980. Site groups: Nottawasaga R. (NWR), Pretty R. (PTR), Collingwood harbour (CWH), Beaver R. (BVR), Bighead R. (BHR), Remote nearshore (RE); Open bay (OB).

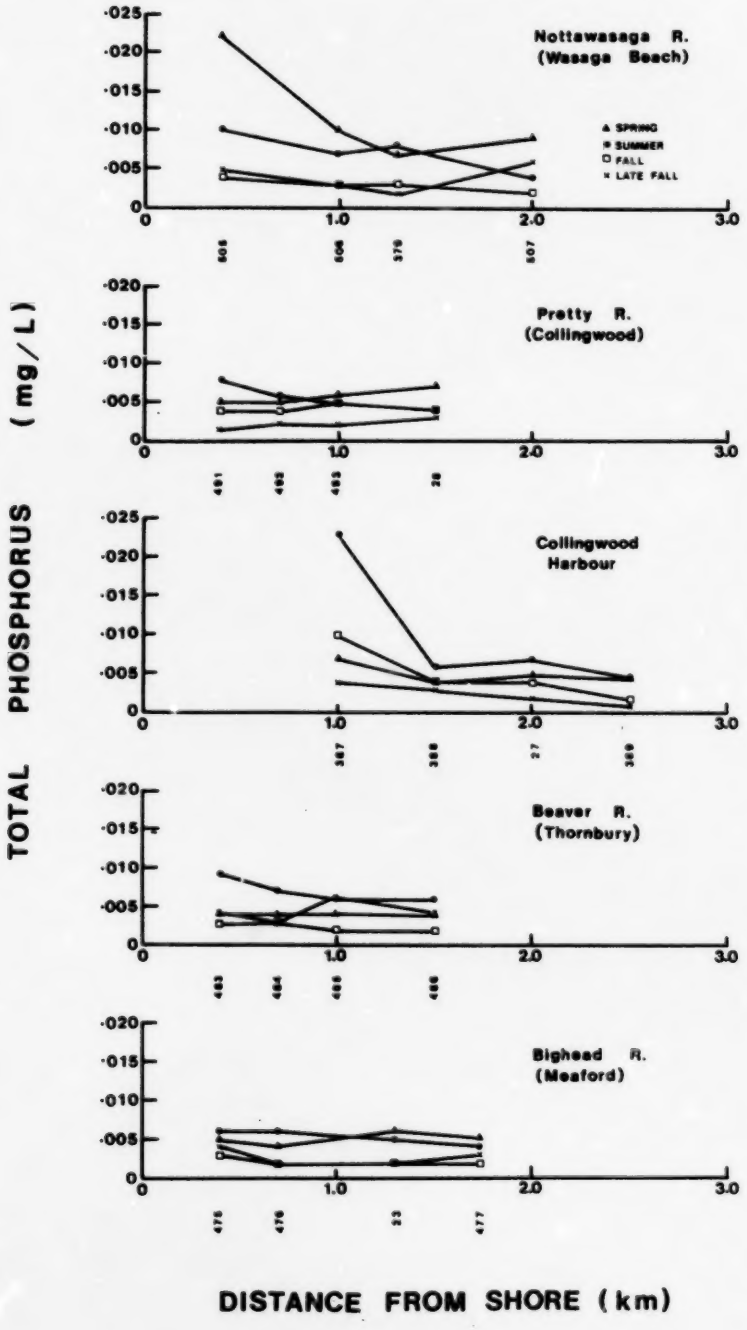

Fig. 3 Total phosphorus cruise means off harbour and river mouths in Nottawasaga Bay, 1980.

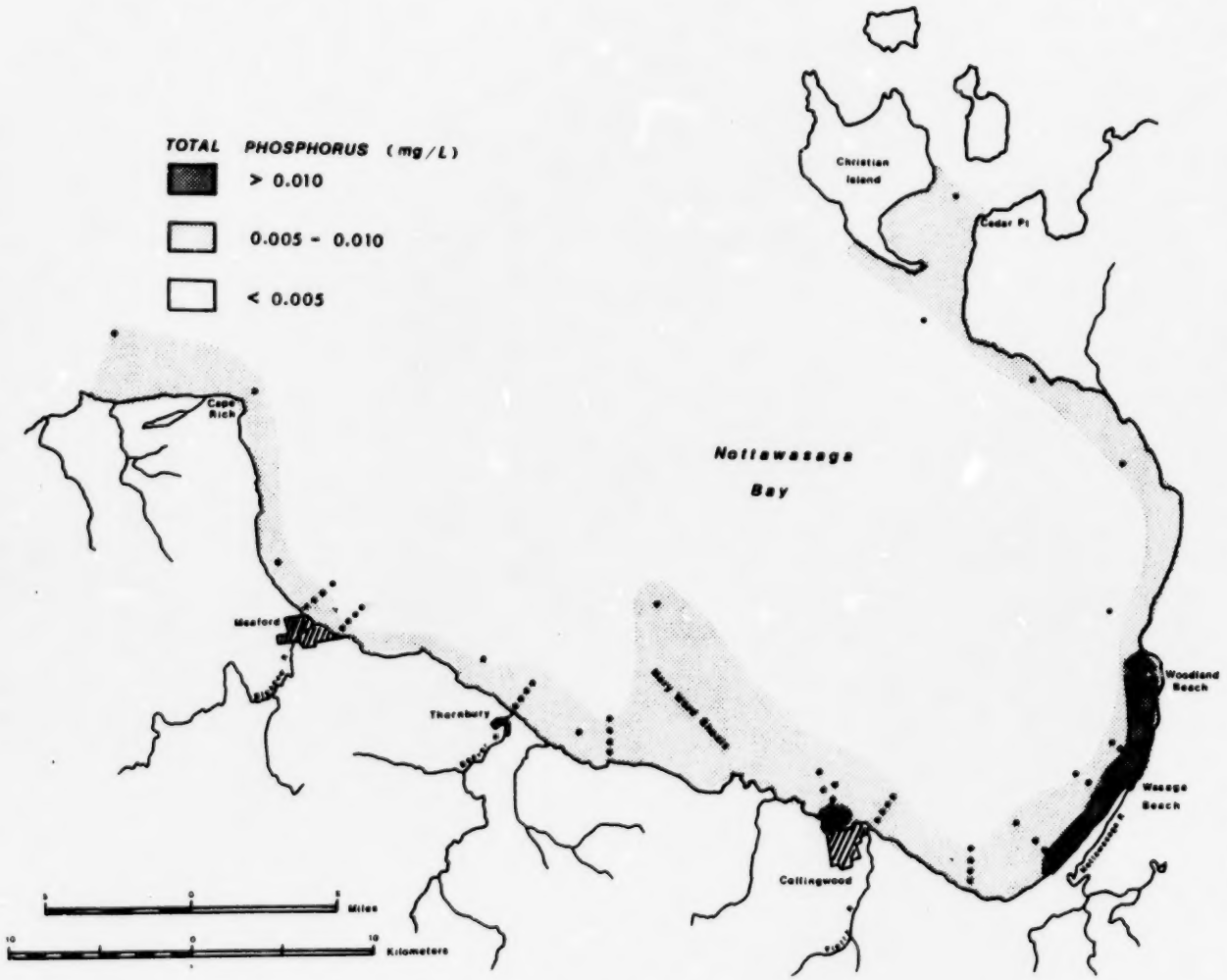

Fig. 4 Zones of total phosphorus concentration in Nottawasaga Bay, 1980. Zonation is based on the "maximum" mean value at each site over the four sampling cruises.

Nitrogen

Nitrogen is essential for algal growth and may become limiting when phosphorus is in excess. Yearly mean concentrations of nitrate-nitrite nitrogen ($NO_3 + NO_2$), a readily utilizable form of inorganic nitrogen, showed little variation among the site groups indicative of P-limited conditions; $NO_3 + NO_2$ values ranged from 0.246 to 0.260 mg/L (Table 2). In general, mean $NO_3 + NO_2$ concentrations were lowest during summer and fall and highest during spring and late fall (Fig. 5). Only the Nottawasaga River showed a pronounced lakeward gradient in $NO_3 + NO_2$ concentration, evident to at least 1 km offshore (Fig. 6).

Yearly mean levels of total Kjeldahl nitrogen (TKN) varied between 0.148 and 0.194 mg/L confirming minimal variability of organic nitrogen in the study area (Table 2). Yearly mean concentrations of ammonia (NH_3), an unstable inorganic form of nitrogen, showed marked differences between site groups. Open bay concentrations averaged 0.002 mg/L, while the Collingwood harbour area averaged 0.018 mg/L; the remaining mean values ranged between 0.010 and 0.012 mg/L. Elevated NH_3 levels near Collingwood harbour were due to municipal wastewater discharge (Ross and Chatterjee 1977), while higher than background levels in the remote nearshore probably reflected recent agricultural runoff and minimal biological utilization.

Silicate

Silicate is an indispensable compound in the synthesis of diatom cell walls. Yearly mean reactive silicate concentrations (as Si) in nearshore Nottawasaga Bay varied between 0.50 and 0.66 mg/L, about half that of the open bay waters (Table 2). This difference in silicate concentration is probably the result of enhanced utilization by nearshore diatom populations and continuous inputs of silicate to open waters from granitic rocks of the north and east shores of Georgian Bay. Mean silicate concentrations in both nearshore and open bay waters did not vary greatly from month to month and only the Nottawasaga River showed evidence of silicate loading from the surrounding watershed (Fig. 7 and 8).

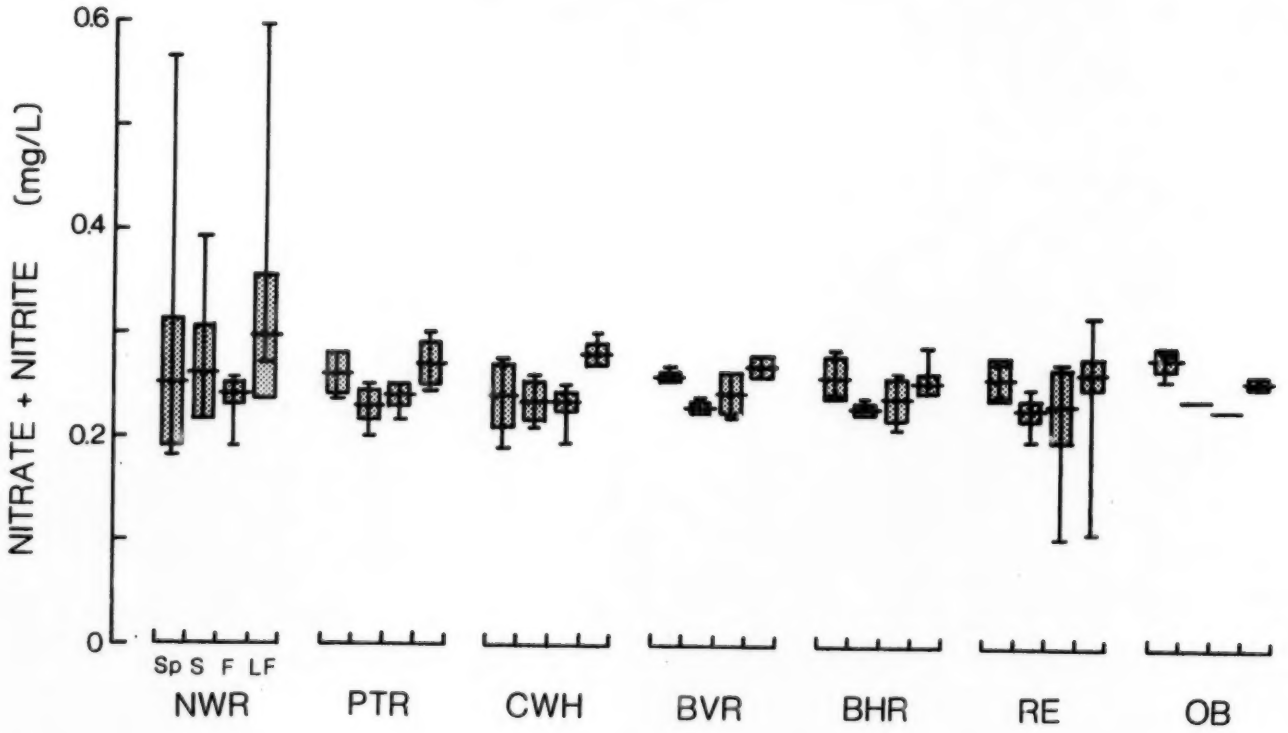

Fig. 5 Nitrate-Nitrite nitrogen summary statistics for site groups in Nottawasaga Bay during spring (SP), summer (S), fall (F) and late fall (LF), 1980. Site groups: Nottawasaga R. (NWR), Pretty R. (PTR), Collingwood harbour (CWH), Beaver R. (BVR), Bighead R. (BHR), Remote nearshore (RE); Open bay (OB). See Fig. 2 for legend.

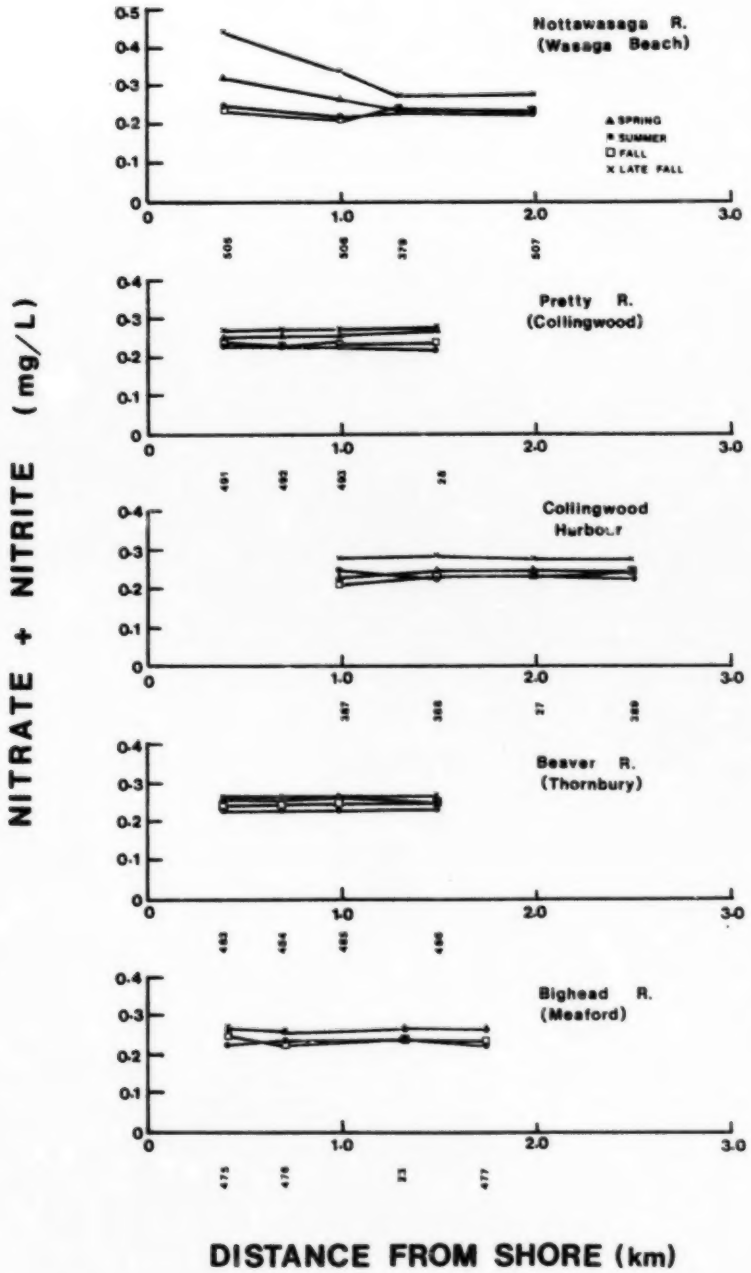

Fig. 6 Nitrate-Nitrite nitrogen cruise means off harbour and river mouths in Nottawasaga Bay, 1980.

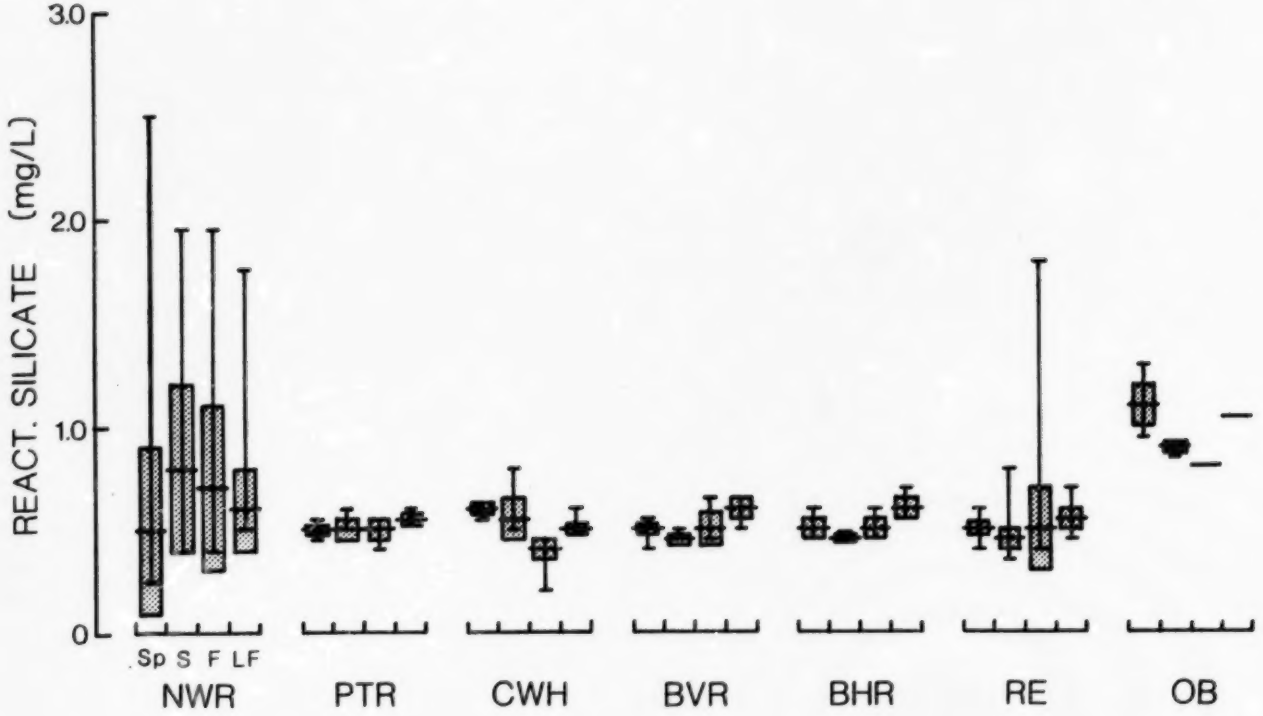

Fig. 7 Reactive silicate summary statistics for site groups in Nottawasaga Bay during spring (SP), summer (S), fall (F) and late fall (LF), 1980. Site groups: Nottawasaga R. (NWR), Pretty R. (PTR), Collingwood harbour (CWH), Beaver R. (BVR), Bighead R. (BHR), Remote nearshore (RE); Open bay (OB). See Fig. 2 for legend.

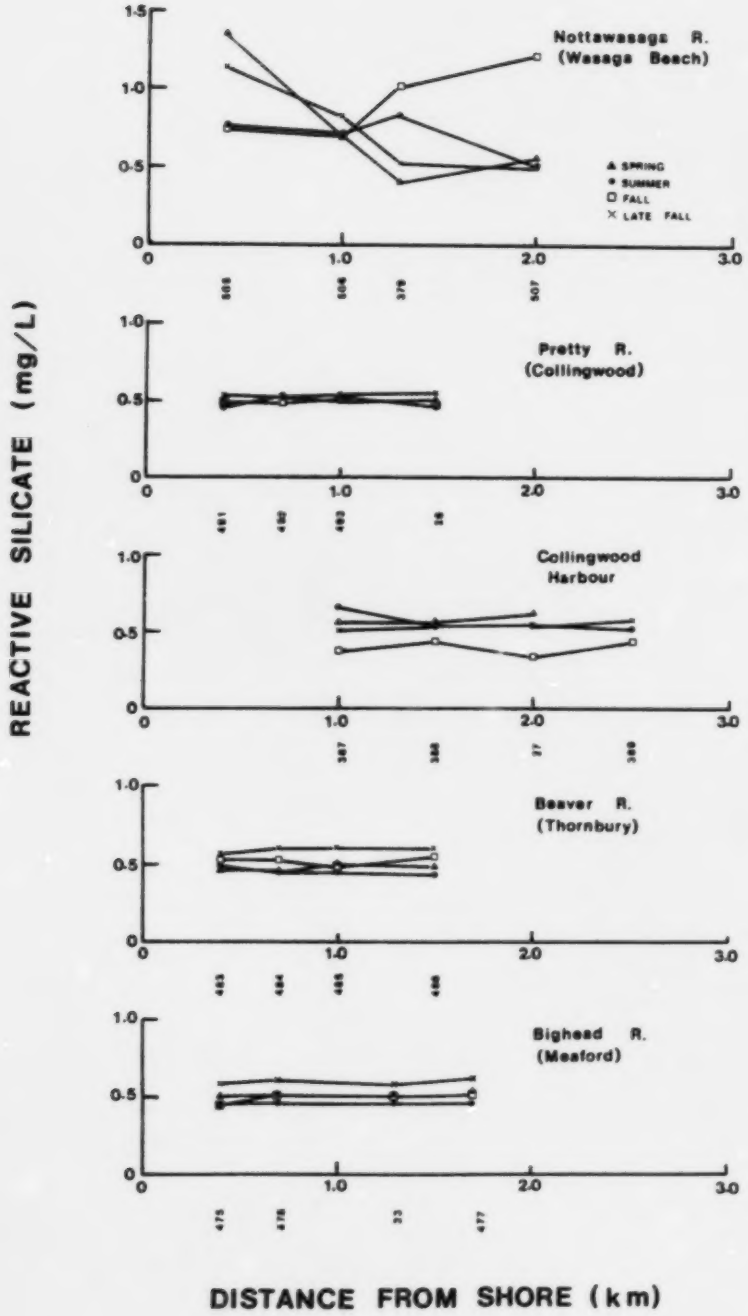

Fig. 8 Reactive silicate cruise means off harbour and river mouths in Nottawasaga Bay, 1980.

7.2 MAJOR IONS

Chloride, a conservative ion useful in tracing water masses, is the most abundant dissolved ion in Lake Huron waters (Ross and Chatterjee 1977). In Nottawasaga Bay, differences between nearshore and open bay chloride concentrations were slight. Yearly mean chloride levels in the nearshore ranged between 5.0 and 5.3 mg/L, while the open bay averaged 4.9 mg/L (Table 2). Mean chloride concentrations were fairly stable over time at most locations in Nottawasaga Bay (Fig. 9). The Nottawasaga River, however, showed elevated chloride levels in the spring and late fall and Collingwood harbour had increased levels in summer. At both of these locations, elevated chloride concentrations were apparent to about 1 km offshore (Fig. 10).

Conductivity is an indirect measure of the concentration of the various ions in solutions and is routinely used to detect changes in water quality. Yearly mean conductivity values showed minor variation among the Nottawasaga Bay site groups, although like chloride, the highest levels were recorded at the Nottawasaga River and Collingwood Harbour, possibly due to a combination of road salt run-off (spring and late fall) and municipal waste water discharge. In general, however, the relatively high conductivity of Nottawasaga Bay waters reflects the local limestone lithology of the region (Table 2).

7.3 TRANSPARENCY

Secchi depth (SD) is the depth at which a circular black and white disc, lowered from the water surface, disappears. Thus, SD provides a relative measure of water transparency, which under normal conditions, correlates rather well with parameters such as algal biomass, turbidity and underwater light intensities. Yearly mean SD varied from 3.5 m and 3.8 m at Collingwood Harbour and the Nottawasaga River to 6.3 m at the Bighead River, indicating a considerable range in water transparency in nearshore Nottawasaga Bay (no SD data is available for the open bay)(Table 2). The relatively turbid waters at Collingwood Harbour and the Nottawasaga River reflect higher concentrations of algae and suspended material

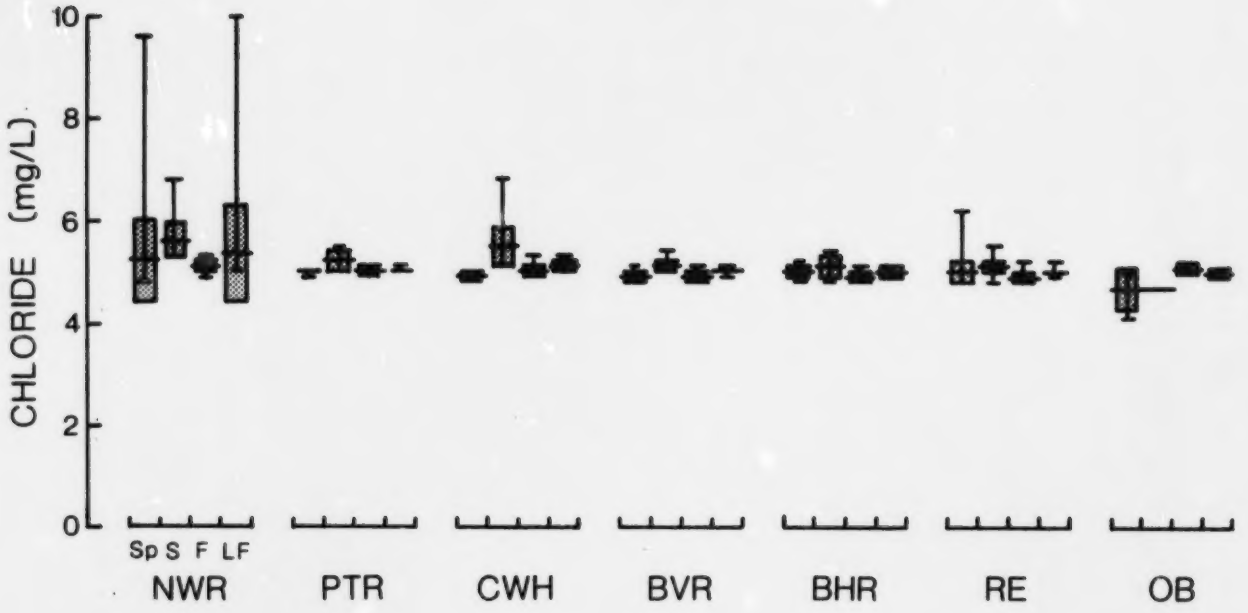

Fig. 9 Chloride summary statistics for site groups in Nottawasaga Bay during spring (SP), summer (S), fall (F) and late fall (LF), 1980. Site groups: Nottawasaga R. (NWR), Pretty R. (PTR), Collingwood harbour (CWH), Beaver R. (BVR), Bighead R. (BHR), Remote nearshore (RE); Open bay (OB). See Fig. 2 for legend.

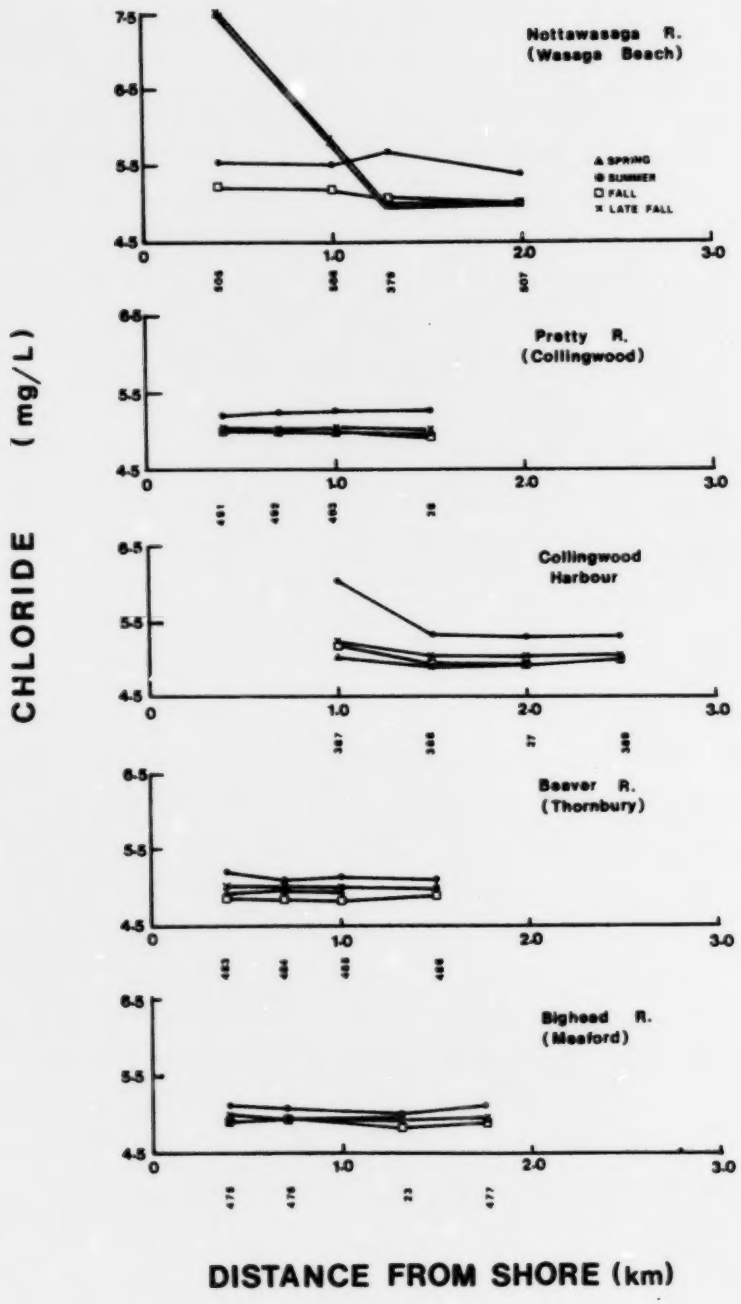

Fig. 10 Chloride cruise means off harbour and river mouths in Nottawasaga Bay, 1980.

characteristic of mixing zones. Water transparency was least impaired at the Bighead River because of the comparatively narrow littoral zone in this area contributing to minimal resuspension of sediments (from wave action) and enhanced exchange with offshore waters.

The Nottawasaga River, Pretty River and Collingwood Harbour showed minor, but continual improvement, in mean SD values from summer through late fall in response to decreasing algal densities. The remaining nearshore groups showed improved water transparency in the summer and late fall, again, consistent with changes in algal densities (Fig. 11). All of the nearshore site groups in Nottawasaga Bay showed an increasing lakeward gradient in mean SD at one or more times during the year. The trend was quite evident at all groups, except the Bighead River which showed only a minor deterioration in transparency during the fall (Fig. 12).

7.4 BACTERIA

Bacterial water quality indicators can reflect the presence of sewage or fecal matter and the risk of contracting disease from pathogens therein. None of the site groups in Nottawasaga Bay experienced summer mean densities of total coliform, fecal coliform, fecal streptococci and Pseudomonas aeruginosa (a pathogenic organism) in violation of Provincial public health standards (Table 3); however, individual sites closest to some harbour and river mouths did show elevated bacterial levels (Fig. 13). Site 387 off Collingwood Harbour exhibited mean fecal coliform counts approaching the MOE criteria of 100 counts per 100 mL. In addition, the ratio of fecal coliforms to fecal streptococci was close to 4.0, suggestive of human fecal contamination from domestic sewage.

7.5 PHYTOPLANKTON

Chlorophyll a

Chlorophyll a concentration is used as an inexpensive, although sometimes inaccurate, measure of algal density and subsequently as a trophic indicator because of its expected response to changes in

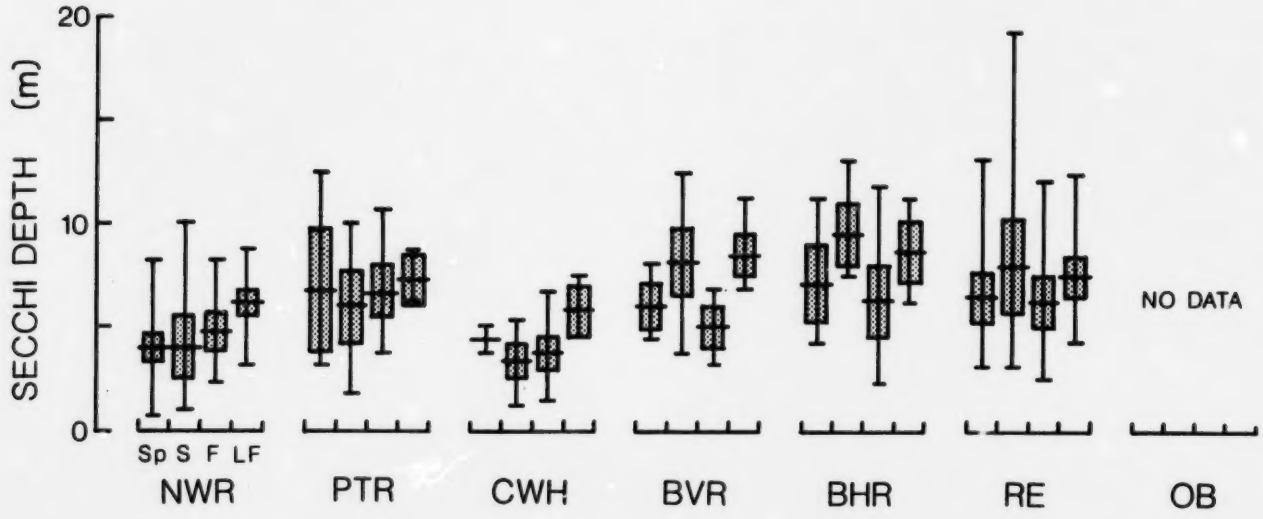

Fig. 11 Secchi depth summary statistics for site groups in Nottawasaga Bay during spring (SP), summer (S), fall (F) and late fall (LF), 1980. Site groups: Nottawasaga R. (NWR), Pretty R. (PTR), Collingwood harbour (CWH), Beaver R. (BVR), Bighead R. (BHR), Remote nearshore (RE); Open bay (OB). See Fig. 2 for legend.

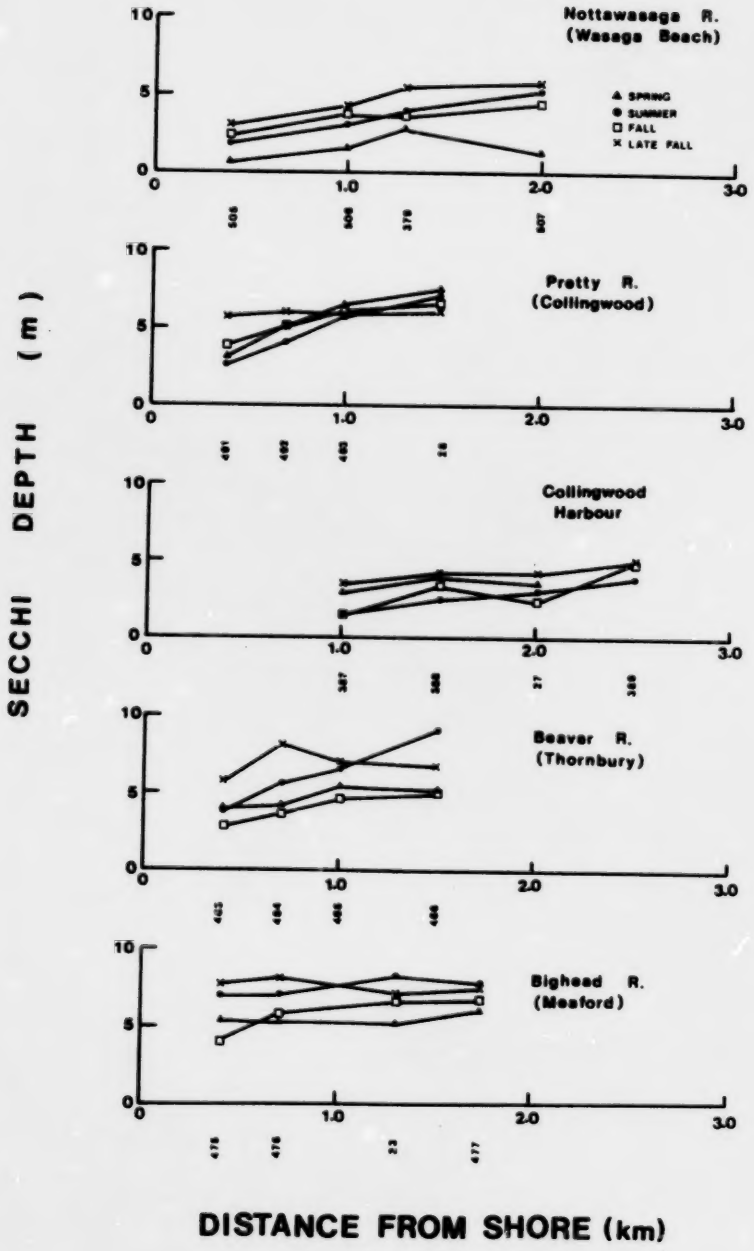

Fig. 12 Secchi depth cruise means off harbour and river mouths in Nottawasaga Bay, 1980.

Table 3. Summary of bacterial water quality indicators in Nottawasaga Bay during summer, 1980. Geometric cruise mean estimates precede ± standard deviation, (N) and minimum-maximum values. Absolute values of 'less than' and 'greater than' counts were used in calculations of means and standard deviations.

	Nottawasaga R. (Wasaga Beach)	Pretty R. (Collingwood)	Collingwood Harbour	Beaver R. (Thornbury)	Bighead R. (Meaford)	Remote Nearshore	Open Bay
Total Coliform	20 ± 5 (48) L4 - 1100	28 ± 4 (12) L4 - 142	56 ± 7 (12) 4 - 3000	23 ± 2 (12) 8 - 40	14 ± 5 (22) L4 - 4500	14 ± 4 (58) L4 - G600	ND
Fecal Coliform	8 ± 4 (48) L4 - 276	10 ± 3 (12) L4 - 68	22 ± 2 (12) L4 - 328	6 ± 2 (12) L4 - 68	8 ± 3 (22) L4 - 424	5 ± 2 (59) L4 - 48	ND
Fecal Streptococci	5 ± 2 (48) L4 - 132	5 ± 2 (12) L4 - 16	7 ± 2 (12) L4 - 32	7 ± 3 (12) L4 - 88	5 ± 3 (22) L4 - 408	5 ± 2 (59) L4 - 96	ND
Pseudomonas aeruginosa	4 ± 1 (48) L4 - 12	4 ± 0 (12) L4 - L4	4 ± 1(12) L4 - 12	6 ± 3 (11) L4 - 64	6 ± 2 (22) L4 - 88	5 ± 2 (59) L4 - 64	ND
FC : FS	1.6	2.0	3.0	0.8	1.5	1.0	ND

ND No data.
L Less than.
G Greater than.

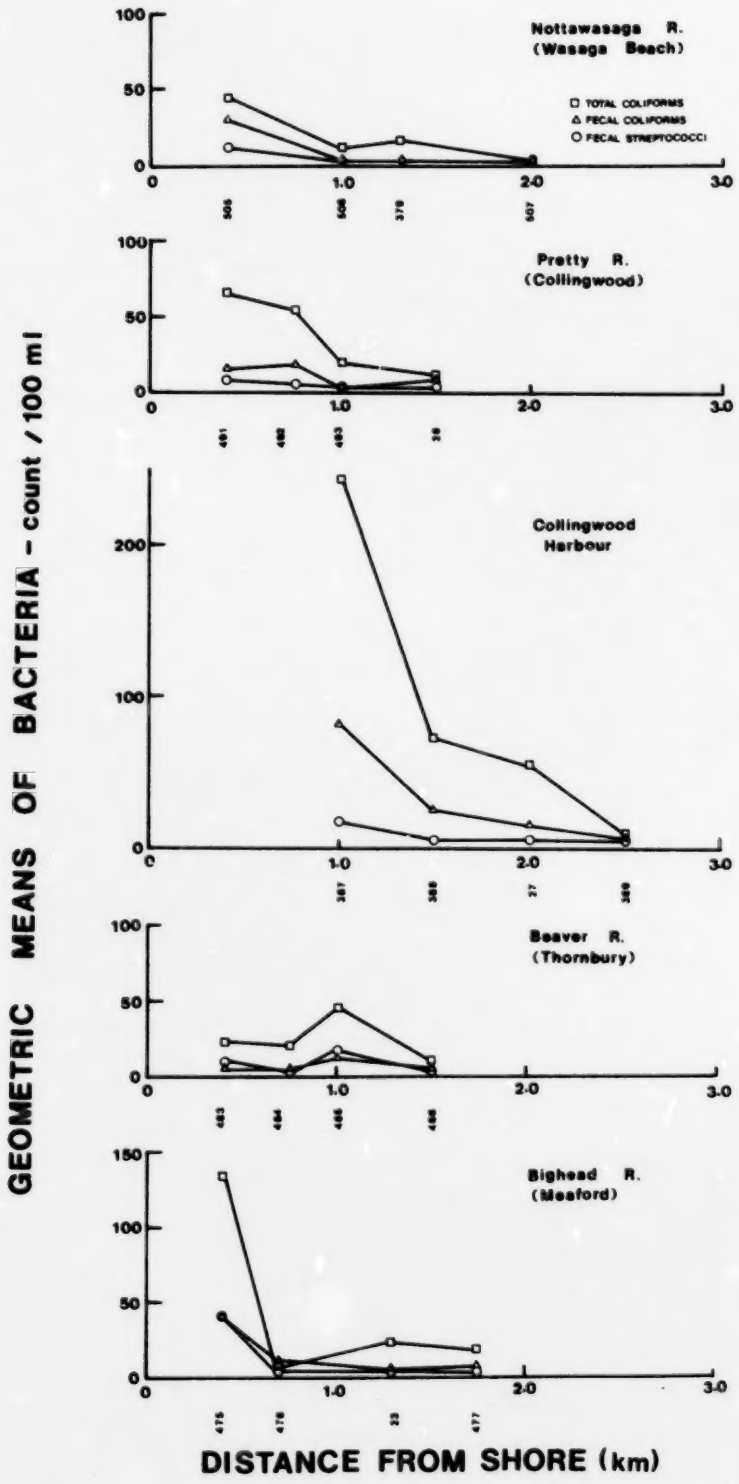

Fig. 13 - Bacteriological cruise means off harbour and river mouths in Nottawasaga Bay during summer, 1980.

nutrient supply. Yearly mean concentrations of chlorophyll a (corrected) ranged from 0.87 to 0.65 µg/L at the Nottawasaga River, Pretty River and Collingwood Harbour and from 0.54 to 0.56 µg/L at the Beaver River, Bighead River and remote site group (no comparable chlorophyll a data were available for the open bay)(Table 2).

The site groups with the lower chlorophyll a concentrations exhibited a weak bimodal pattern, displaying peak levels in the spring and fall, while the site groups with higher chlorophyll a concentrations (NWR, CWH; PTR) experienced peak levels in the spring only, followed by decreasing concentrations over time (Fig. 14). Decreasing lakeward gradients in chlorophyll a concentration were most evident off Collingwood harbour and the Nottawasaga River, symptomatic of local nutrient enrichment (Fig. 15). The restricted distribution of these enriched areas is shown in Fig. 16 which depicts the "maximum" mean chlorophyll a concentration at each site over the four sampling cruises.

Biomass and Taxonomy

Phytoplankton abundance and taxonomic composition are sensitive indicators of water quality. Due to the scarcity of phytoplankton data in Nottawasaga Bay (only nine sites and three sample dates) sample sites were divided into two groups (instead of seven) to assess enrichment effects. The "affected" group included those sites in proximity to harbour and river mouth areas (sites 486, 28, 29), while the "remote" group constituted the remaining six sites away from any obvious nutrient sources (sites 20, 21, 26, 31, 33, 86)(Fig. 1).

The yearly mean phytoplankton density for the three affected sites (0.24 mm^3/L) was higher than the mean for the six remote sites (0.19 mm^3/L) suggesting an effect of enrichment to at least 1.5 km distant from the respective nutrient sources. For both groups of sites, spring phytoplankton densities exceeded summer and fall values while summer densities were lowest. Monthly mean values ranged from 0.45 to 0.13 mm^3/L at the affected group and from 0.32 to 0.08 mm^3/L at the remote group (Fig. 17).

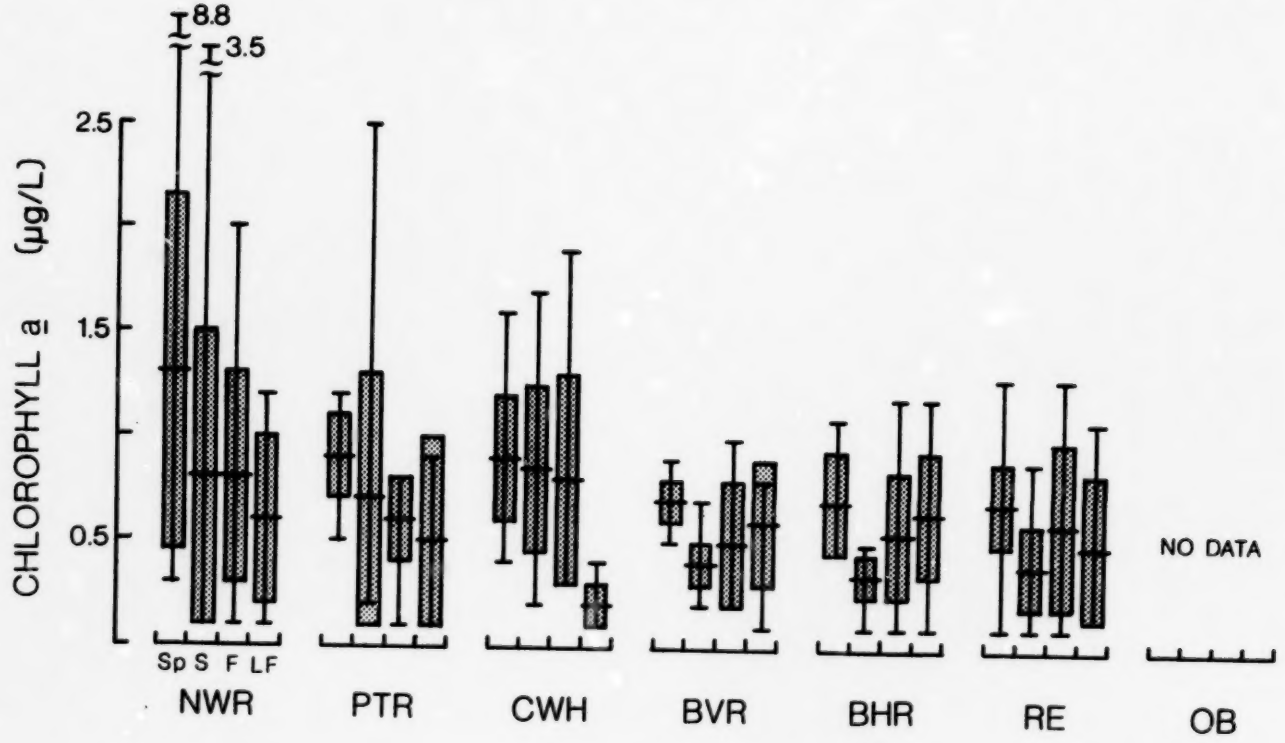

Fig. 14 Chlorophyll a (corrected) summary statistics for site groups in Nottawasaga Bay during spring (SP), summer (S), fall (F) and late fall (LF), 1980. Site groups: Nottawasaga R. (NWR), Pretty R. (PTR), Collingwood harbour (CWH), Beaver R. (BVR), Bighead R. (BHR), Remote nearshore (RE); Open bay (OB). See Fig. 2 for legend.

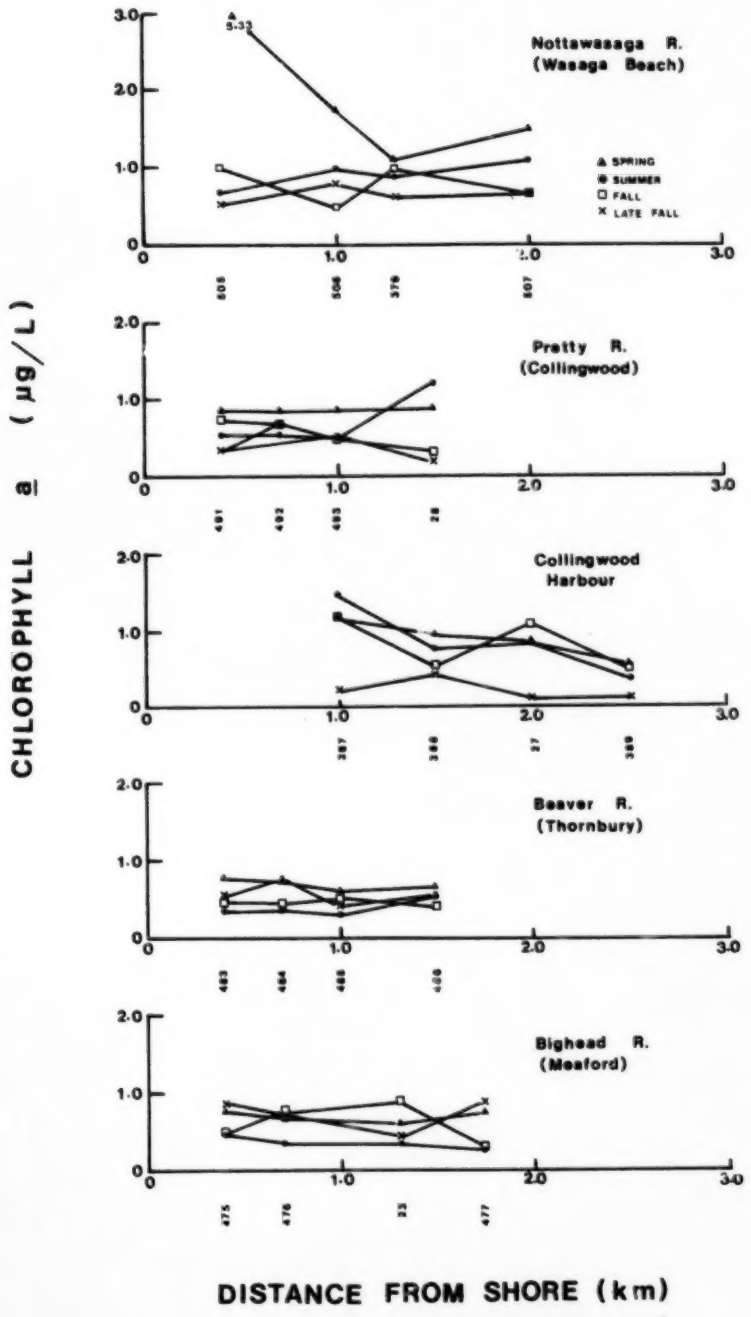

Fig. 15 Chlorophyll a (corrected) cruise means off harbour and river mouths in Nottawasaga Bay, 1980.

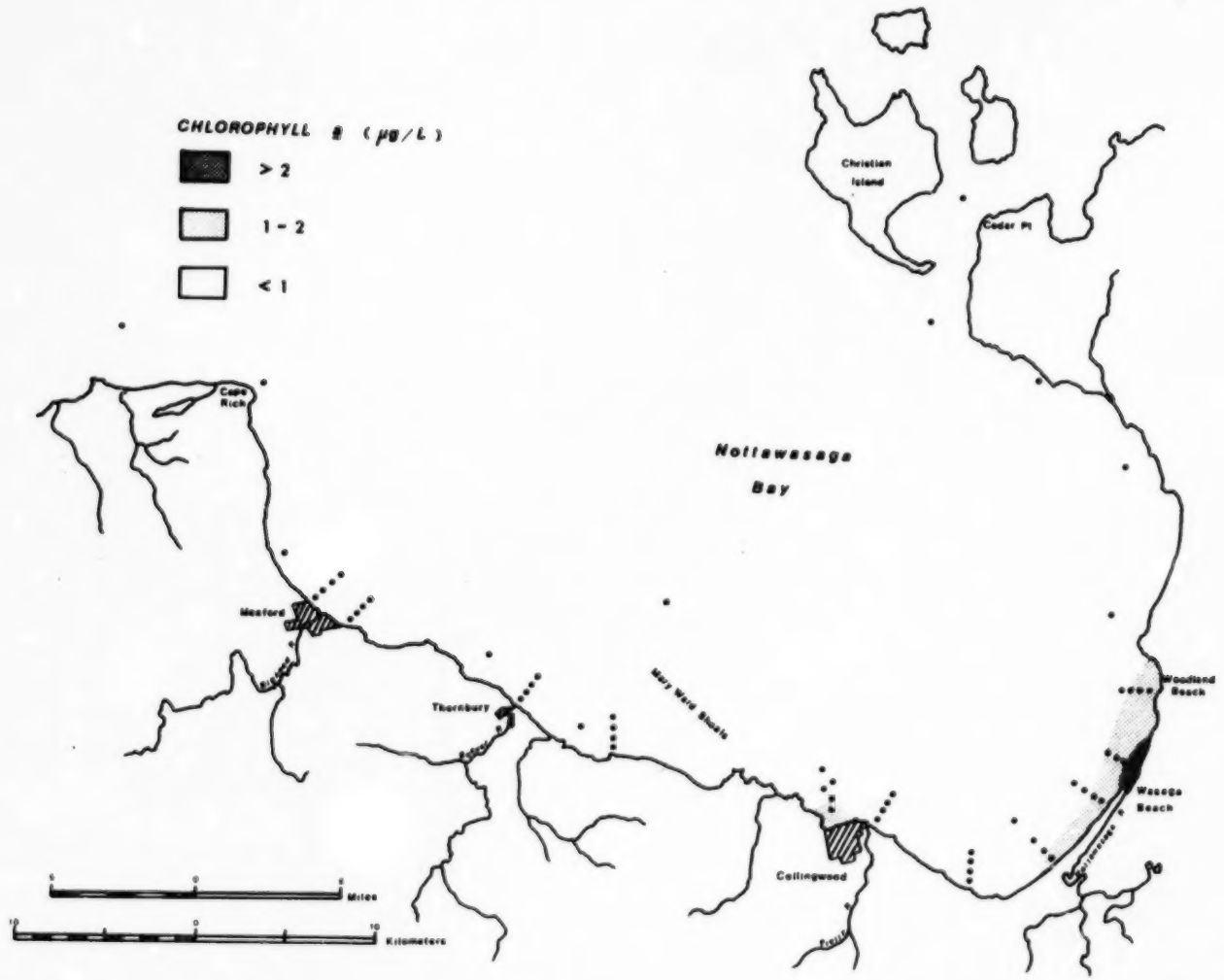

Fig. 16 Zones of chlorophyll a concentration (corrected) in Nottawasaga Bay, 1980. Zonation is based on the "maximum" mean value at each site over the four sampling cruises.

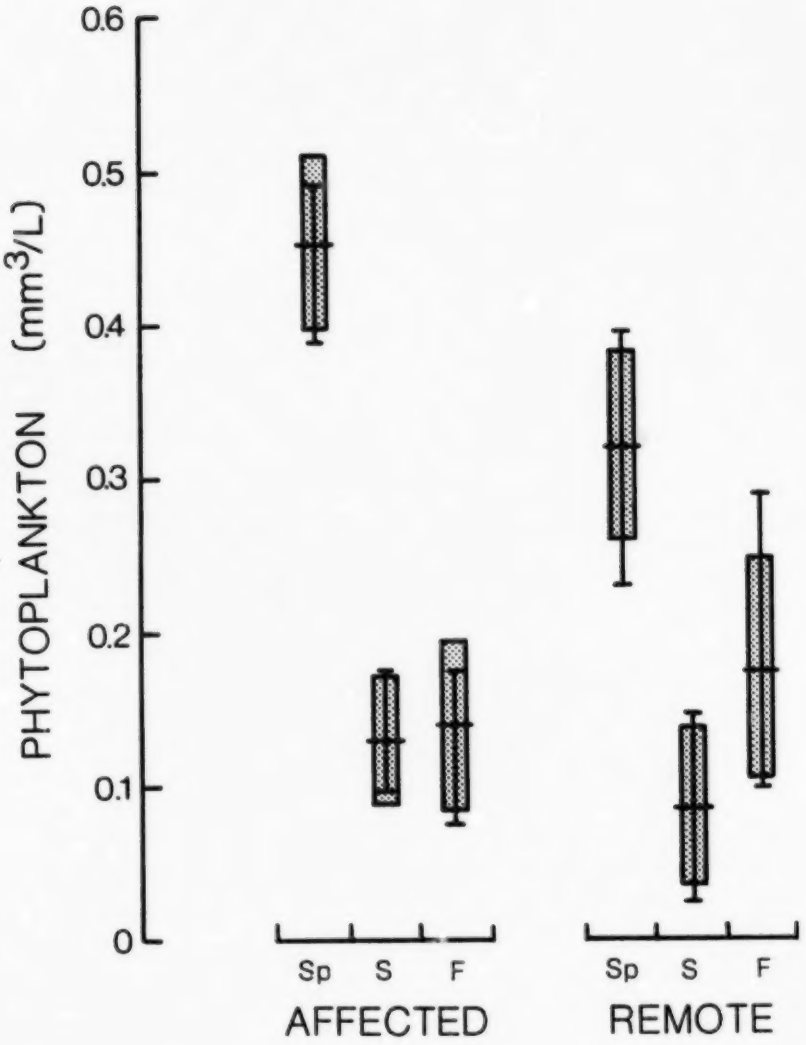

Fig. 17 Phytoplankton density summary statistics for the "remote" and "affected" site groups in Nottawasaga Bay during spring (SP), summer (S) and fall (F), 1980.

The dominant algal class at all nine sites was the Bacillariophyceae (diatoms) which contributed between 55 and 74% of the average phytoplankton biomass. Other classes comprised less than 15% of the total; however, considerable site-to-site differences in the representation of some algal groups were apparent, especially among the Dinophyceae and Cyanophyceae (Fig. 18).

Most of the diatoms present in Nottawasaga Bay during June-September of 1980 were species generally considered to be eurytopic (e.g., Tabellaria fenestrate (Lyngb.) Kütz., T. flocculosa (Roth.) Kütz., Asterionella formosa Hass., Fragilaria crotonensis (Kitton) or indicators of oligotrophic status (e.g., Cyclotella comta (Ehr.) Kütz., C. comensis Grun., C. stelligera (Cl. et Grun.) V.H., Rhizosolenia eriensis H.L. Sm.). The presence in minor quantities of the bloom-forming blue-green algae Anabaena and Oscillatoria (less than 0.03 mm^3/L) and the eutrophic diatom species Stephanodiscus binderanus (Kütz.) Krieger, S. hantzschii Grun., S. astraea (Ehr.) Grun. and Cyclotella meneghiniana Kütz., suggest that the algal flora of these waters is influenced to some minor degree by nutrient inputs in excess of those normally associated with oligotrophic waters (see Nicholls et al. 1977, Stoermer 1978; Munawar and Munawar 1981). In general, however, the combined average phytoplankton and total P concentrations at these nine nearshore sites suggest a trophic status more similar to that of the open waters of Lakes Superior and Huron than of the more eutrophic areas of the Great Lakes (Fig. 19).

VIII CONCLUSIONS

During the ice-free period of 1980, obvious signs of eutrophication in nearshore Nottawasaga Bay were local to two major discharge points: mesotrophic conditions occurred within a 1-2 km radius of Collingwood harbour and within a 15 km long by 1-2 km wide stretch of shoreline bracketing the Nottawasaga River mouth. With minor exceptions these locations consistently experienced reduced water quality relative to the open bay. They did not, however, extend to the Mary Ward Shoals, a major fish spawning ground susceptible to growth of the attached alga Cladophora. Reductions in water quality were only occasionally evident off the Pretty River (Collingwood), Beaver River (Thornbury) and Bighead

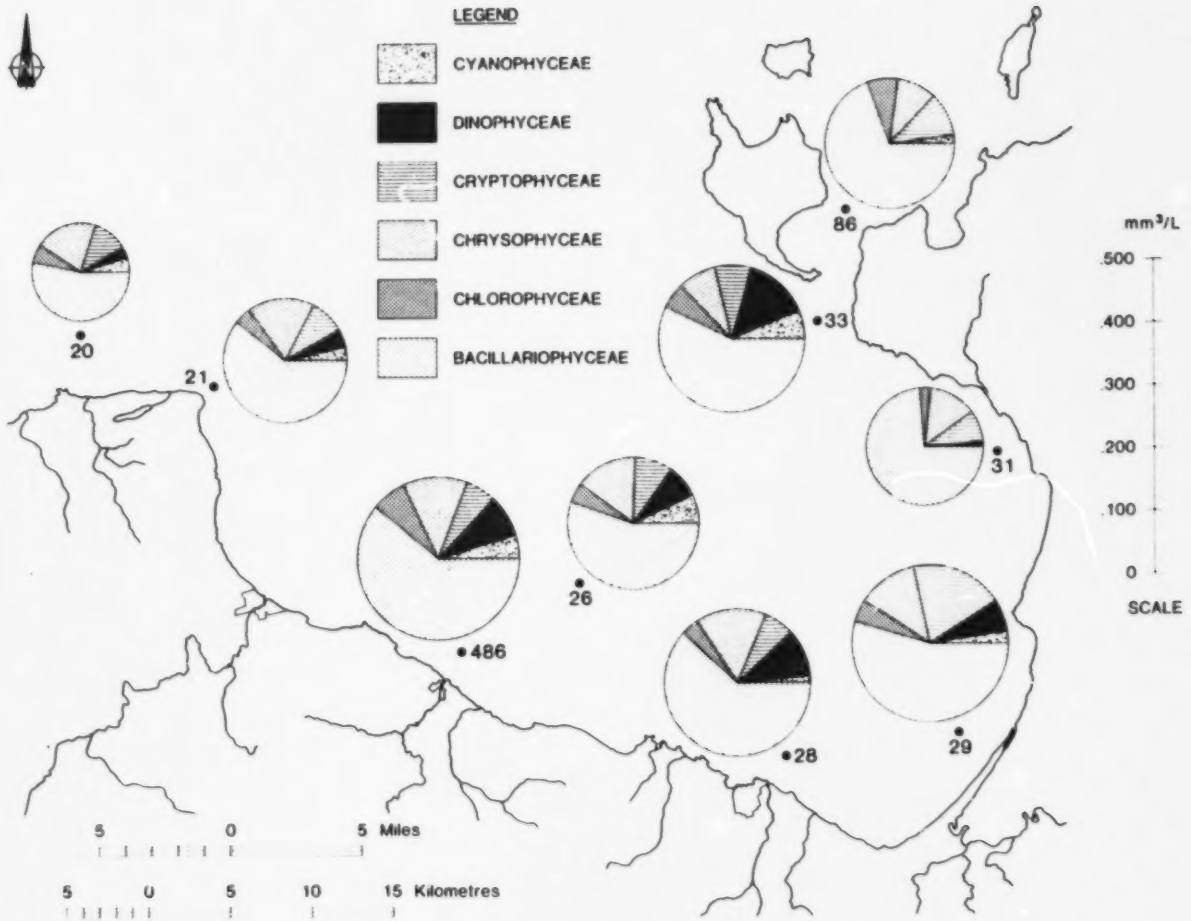

Fig. 18 Phytoplankton densities and taxonomic composition at nine nearshore sites in Nottawasaga Bay for the ice-free period (spring, summer; fall), 1980.

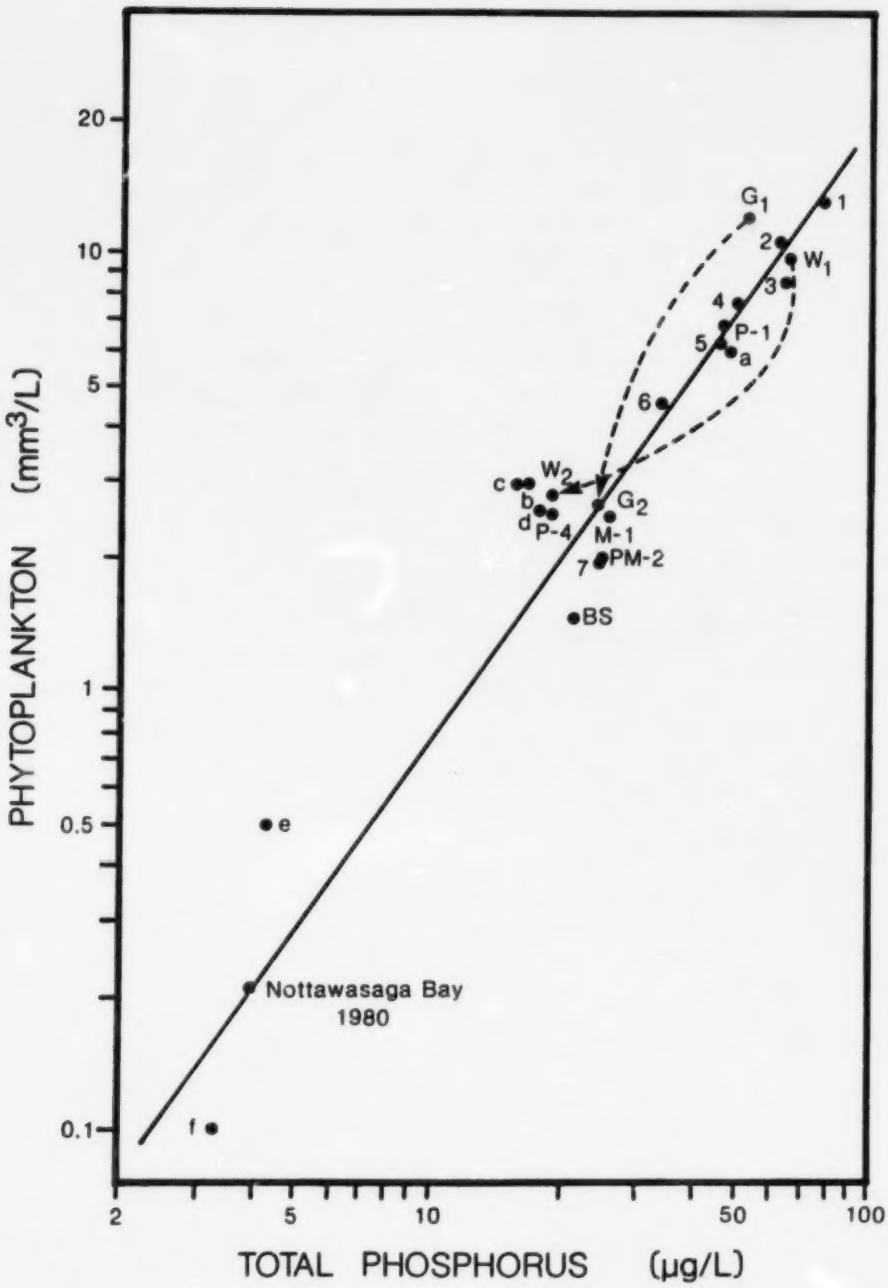

Fig. 19 Average (ice-free period) total phosphorus concentration and total phytoplankton biomass at nine nearshore sites in Nottawasaga Bay in relation to other water bodies. See List of Figures for further details.

River (Meaford). Oligotrophy characterized the open bay and the remainder of the nearshore, although differences between these two zones were apparent. The presence of bloom-forming algae and slightly elevated nutrient levels at remote nearshore sites may be cause for concern and warrants further surveillance.

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